

ETA-HTP04

Revision 0

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Hybrid Electric Vehicle Constant Speed Range Tests

Prepared by

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1. Objective

The objective of this procedure is to provide methods for the testing of constant speed range of vehicles participating in HEV America. Testing is conducted in accordance with procedures similar to SAE-J227a (canceled). These methods are not meant to supersede those of the testing facility, those specifically addressed by SAE Test Standards, nor of any regulatory agency who may have or exercise control over the covered activities.

2. Purpose

The purpose of this procedure is to identify acceptable methods for the implementation of a constant speed range test, similar to that identified in SAE J227a, for vehicles operable in "RESS only mode." The SAE J227a Recommended Practice, although canceled, established uniform procedures for testing electric battery-powered vehicles as a total system rather than a collection of its individual subsystems. This procedure shall collect and retain test data as specified in the HEV America Technical Requirements.

3. Documentation

Documentation addressed by this procedure shall be consistent, easy to understand, easy to read and readily reproducible. This documentation shall contain enough information to "stand alone"; that is, be self-contained to the extent that all individuals qualified to review it could be reasonably expected to reach a common conclusion, without the need to review additional documentation. Review and approval of test documentation shall be in accordance with ETA-HAC04, "Review of Test Results." Storage and retention of records during and following testing activities shall be completed as described in Procedure ETA-HAC01, "Control, Close-out and Storage of Documentation."

4. Initial Conditions and Prerequisites

Prior to conduct of any portion of the testing, the following initial conditions and prerequisites shall be met. Satisfactory completion of these items shall be verified as complete and recorded on the 45 MPH Constant Speed Test Data Sheet as contained in Appendix A.

- 4.1 Personnel conducting testing under this procedure shall be familiar with the requirements of this procedure, and when applicable the appropriate SAE Test Instructions, Administrative Control Procedures, and be certified by the Program Manager, Test Manager or specific Test Engineer prior to commencing any testing activities.

- 4.2 All documentation required to complete the testing shall be completed, approved and issued (past it's effective date) prior to commencing the testing it addresses.
- 4.3 Road Testing
 - 4.3.1 Road tests shall be performed on a road or test track which is level to within 1%.
 - 4.3.2 RESS temperatures at the beginning of the test shall less than 120°F (49°C) and should be less than 100°F (38°C)
 - 4.3.3 Ambient temperature during road testing shall be within the range of 32°F (0°C) to 100°F (38°C).
 - 4.3.4 The average wind speed at the test site during the test shall not exceed 10 mph (16 km/h). Wind gusts shall not exceed 12.3 mph (20 kph).
- 4.4 Vehicle shall be tested in its normal configuration with normal appendages (mirrors, bumpers, hubcaps, etc.). Certain items (hub caps, etc.) may be removed where necessary for safety on the dynamometer.
- 4.5 Vehicles shall be tested at curb weight plus 332 pounds. Consideration should be given to how adding instrumentation will affect the test weight and balance of the vehicle.
- 4.6 Tires provided with the vehicle shall be the standard tire offered by the Vehicle Supplier, and shall be inflated to the Supplier's (placard) recommended cold inflation pressures. This pressure shall not exceed the maximum allowable pressure imprinted upon the tire's sidewall.
- 4.7 Normal Supplier's recommended lubricants shall be employed.
- 4.8 Accessories shall not be used during testing activities.
- 4.9 Full charge conditions for the RESS shall be established using the Supplier's recommended charging procedure and equipment in accordance with ETA-HTP08, "RESS Charging."
- 4.10 The following data shall be collected during conduct of the various tests specified by this procedure. Overall error in recording or indicating instruments shall not exceed $\pm 2\%$ of the maximum value of the variable being measured. Periodic calibration shall be performed and documented to ensure compliance with this requirement.
 - 4.10.1 RESS voltage versus time;
 - 4.10.2 RESS current versus time;
 - 4.10.3 Vehicle speed versus time;
 - 4.10.4 Distance versus time;

- 4.10.5 RESS temperature versus time;
- 4.10.6 RESS watts versus time;
- 4.11 Environmental conditions during the testing shall be recorded and include, at a minimum, the following:
 - 4.11.1 Range of ambient temperature during the test;
 - 4.11.2 Range of wind velocity during the test;
 - 4.11.3 Range of wind direction during the test.
- 4.12 Verify that Procedures ETA-HAC06, "Receipt Inspection," and ETA-HTP11, "Vehicle Verification," have been completed.
- 4.13 A description of the test route, road surface type and condition, and lengths and grades of test route, shall be recorded.
- 4.14 The date and starting and ending times shall be recorded.
- 4.15 The starting and ending vehicle odometer readings shall be recorded.
- 4.16 All instrumentation used in the test shall be listed on Appendix D, attached to the test data sheets/results, and shall include the following information:
 - 4.16.1 Manufacturer
 - 4.16.2 Model Number
 - 4.16.3 Serial Number
 - 4.16.4 Last Calibration date
 - 4.16.5 Next Calibration date
- 4.17 The speed-time measuring device and other necessary equipment shall be installed so that they do not hinder vehicle operation or alter the operating characteristics of the vehicle. Mounting will nominally be at the rear of the vehicle.
- 4.18 Any deviation from the test procedure, and the reason for the deviation, shall be recorded in accordance with ETA-HAC02.
- 4.19 All documentation required to complete the testing shall be completed, approved and issued prior to commencing the testing it addresses.
- 4.20 During data reduction, the actual distance traveled and the corresponding DC Kilowatt-hour consumption shall be determined. These values provide the 100% State of Charge (SOC) mileage and/or kWh meter reading. These two values shall be used throughout the remainder of testing, and shall be the basis for determining SOC's less than 100%.

- 4.21 In addition to the formal completion of all sections of this procedure, Section 5.1 may be completed at additional times as requested by the ETA Program Manager or ETA Test Manager. [Additional tests may be completed to determine changes to the range capability of a vehicle, or if a vehicle's permanently installed instrumentation is suspected of misoperation.]
- 4.22 Each Range Test shall be terminated when the specific requirements of the procedure have been reached. However, if the Supplier's instructions provide guidance concerning when to stop driving the vehicle, the vehicle's range will be the range achieved when the conditions meeting that guidance have occurred. [Example: If the owner's manual/driver's instructions provided with the vehicle provide direction to stop driving upon receipt of a specific telltale or other indication normally available to the driver, the vehicle will be stopped and the test terminated when that telltale/indication has occurred.]
- 4.23 Only test vehicles that are capable of being driven in "RESS only mode" shall be tested using this procedure. Vehicles that are not capable of being tested in an RESS only mode will not be tested in this procedure.

5. Testing Activities Requirements

NOTE

All steps shall be completed in the order written. Deviations from any step or requirement shall have the approval of the Program Manager or Test Manager in accordance with Procedure ETA-HAC02, "Control of Test Conduct."

5.1 Range at 45 mph Constant Speed

The purpose of this section is to (1) Determine the maximum range the vehicle can achieve with the Rechargeable Energy Storage System (RESS) starting at 100% State of Charge (SOC), the vehicle loaded at curb weight plus 332 pounds, and operated at a constant 45 mph. And (2) determine the correlation between the State of Charge indicator and the mileage driven (which will be used to establish partial SOC conditions in other protocols).

This testing shall be completed subject to the initial conditions and prerequisites stated in Section 4 of this procedure.

NOTE

Constant speed testing is only conducted for vehicles operable in "RESS only mode."

- 5.1.1 Instrument the vehicle to obtain, at a minimum, the data identified in Section 4.10. Calibrate the fifth wheel, as necessary.
- 5.1.2 Verify the RESS is fully charged (100% SOC) in accordance with ETA-HTP08, "RESS Charging" and the vehicle is in the "RESS only mode."
- 5.1.3 Record time and the vehicle's odometer reading on Appendix A.
- 5.1.4 Adjust the vehicle's cold tire pressures to match the Supplier's placard value, or the maximum cold inflation pressure imprinted upon the tire's sidewall, whichever is less.
- 5.1.5 From a standing start, accelerate the vehicle under its own power to a speed of 45 mph \pm 1 mph (72 km/h \pm 1.6 km/h). Speed and time may be recorded via a Data Acquisition System (DAS).
- 5.1.6 Each time the vehicle passes the lap marker, record the SOC meter reading and the odometer reading. Each reading shall be recorded in the smallest increment displayed by its respective indicator.

NOTE

All vehicle's tested will be operated in accordance with the requirements of the Supplier's operating manuals/instruction cards/placards. Should the Supplier's requirements for stopping the vehicle be met prior to reaching the criteria in Step 5.1.7, the test shall be terminated. The Official Range will be the range achieved at that point, regardless of remaining capability.

- 5.1.7 Maintain this speed without interruption until an average vehicle lap speed of at least 43 mph (69 km/h) cannot be maintained. If testing is being accomplished at Exponent Inc., continue testing until the vehicle will not maintain 40 mph on the east bound straight-away. Record the final speed, odometer reading and time on Appendix A. (This may be recorded via a DAS.)
- 5.1.8 Pull the vehicle off to the side of the test track. Record the time, mileage, SOC meter and odometer reading on Appendix A. (Time may be recorded via a DAS.)

- 5.1.9 The mileage achieved during this test shall be recorded as the official range mileage for the vehicle being tested.

5.2 Range at Maximum Achievable Speed

The purpose of this section is to determine the maximum range the vehicle can achieve after the vehicle has been standing, not on charge, uncovered, on a simulated parking lot (blacktop, asphalt, etc.) for at least eight hours. The minimum high ambient temperature achieved during this period shall be 100°F. The RESS shall have been fully charged (100% SOC) prior to the standing period. The vehicle shall be loaded at curb weight plus 332 pound and operated at the vehicle's maximum achievable speed, or 65 mph, whichever is less. This testing shall be completed subject to the initial conditions and prerequisites stated in Section 4 of this procedure, as amended by this section.

NOTE

Range at maximum speed testing is only conducted for vehicles operable in "RESS only mode."

- 5.2.1 The vehicle does not require instrumentation for this test. Odometer readings shall be sufficient to determine range.
- 5.2.2 Verify the RESS is at fully charged (100% SOC) in accordance with ETA-HTP08, "RESS Charging" and the vehicle is in the "RESS only mode."
- 5.2.3 Record odometer reading and time on Appendix B.
- 5.2.4 Adjust the vehicle's cold tire pressures to match the Supplier's placard value, or the DOT sidewall pressure, whichever is less.
- 5.2.5 Identify the maximum speed the vehicle achieved when tested to ETA-HTP002. Record the lesser of this value or 65 mph on Appendix B.

NOTE

The vehicle shall be operated at the lower of the two speeds in Step 5.2.5. Transitory operation above 65 mph due to track attitude is allowed.

- 5.2.6 From a standing start, accelerate the vehicle under its own power at wide open throttle to the maximum speed determined in Step 5.2.5

(above). Speed and time may be recorded via a Data Acquisition System (DAS.)

- 5.2.7 Each time the vehicle passes the lap marker, record the SOC meter reading and the odometer reading. Each reading shall be recorded in the smallest increment displayed by its respective indicator.

NOTE

All vehicle's tested will be operated in accordance with the requirements of the Supplier's operating manuals/instruction cards/placards. Should the Supplier's requirements for stopping the vehicle be met prior to reaching the criteria in Step 5.2.8, the test shall be terminated. The Official Range will be the range achieved at that point, regardless of remaining capability.

- 5.2.8 Maintain this speed without interruption until a minimum vehicle speed of at least 40 mph cannot be maintained. Record the final speed, odometer reading and time on Appendix B. (This may be recorded via a DAS.)
- 5.2.9 Pull the vehicle off to the side of the test track. Record the time, miles traveled, and odometer reading on Appendix B. (This may be recorded via a DAS.)

5.3 Calibration of the Vehicle Speedometer

This section should be completed concurrent with completion of ETA-HTP11, "Vehicle Verification," as well as in conjunction with Sections 5.1 and 5.2 of this procedure. It may also be implemented any time the speedometer is suspected of mis-operation. If the calibration is being completed independent of range testing, do not complete steps 5.3.1, 5.3.2 or 5.3.3.

- 5.3.1 When accelerating the vehicle to a predetermined speed of 65 mph, or maximum vehicle speed, record the vehicle speedometer reading compared to the installed Data Acquisition System (DAS) speed reading, in 10 mph increments, up to and including the final speed achieved. [To promote safety, this may be done verbally by speaking to a tape recorder, and then later transcribed into Appendix C.]
- 5.3.2 The error between the speedometer and the DAS readout shall be calculated and the results posted in the vehicle for the driver to use.

- 5.3.3 If the driver notices a difference between the indicated value and the calculated correction factor, this test should be run again.
- 5.3.4 If the vehicle is being operated for the sole purpose of calibrating the speedometer, calibration should be as follows:
 - 5.3.4.1 Ensure the vehicle is instrumented with a DAS.
 - 5.3.4.2 With the vehicle stopped, record the speedometer reading.
 - 5.3.4.3 Accelerate the vehicle to 20 mph; record the speedometer reading and the DAS heads-up display speed readout.
 - 5.3.4.4 Increase vehicle speed in 5 mph increments, recording the speedometer and heads-up display speed read-out at each speed. Continue this until the vehicle has achieved 65 mph, or maximum achievable speed, whichever is less.
 - 5.3.4.5 Develop a calibration reference table, Appendix C, for the speedometer.
 - 5.3.4.6 Mount the calibration reference table in the subject vehicle adjacent to the speedometer.

6. GLOSSARY

- 6.1 RESS kilowatt-hour (kWh) Capacity - The capacity of a RESS in ampere-hours determined as a function of the total distance traveled by the vehicle during performance of the 45 mph Constant Speed Range Test portion of ETA-HTP004.
- 6.2 Curb Weight - The total weight of the vehicle including batteries, lubricants, and other expendable supplies but excluding the driver, passengers, and other payloads.
- 6.3 Effective Date - The date, after which a procedure has been reviewed and approved, that the procedure can be utilized in the field for official testing.
- 6.4 Fifth Wheel - A calibrated instrument used to measure a vehicle's speed and distance independent of the vehicles on-board systems.
- 6.5 Gross Vehicle Weight Rating (GVWR) - The maximum design loaded weight of the vehicle specified by the Supplier.
- 6.6 HEV America - Hybrid Electric Vehicle America Performance Test Program, the DOE sponsored test program for independently assessing the performance of vehicles submitted for testing.
- 6.7 Initial Conditions - Conditions that shall exist prior to an event occurring.
- 6.8 Initial State of Charge (SOC) - RESS SOC at the beginning of a test.

- 6.9 Prerequisites - Requirements that must be met or resolved prior to an event occurring.
- 6.10 Program Manager - As used in this procedure, the individual within Electric Transportation Applications responsible for oversight of HEV America. [Subcontract organizations may have similarly titled individuals, but they are not addressed by this procedure.]
- 6.11 Rechargeable Energy Storage System (RESS) – A component or system of components that stores energy and for which its supply of energy is rechargeable by an electric motor-generator system, an off-vehicle energy source, or both. Examples of RESS's for HEVs include batteries, capacitors and electromechanical flywheels.
- 6.12 Shall - This word is used to indicate an item which requires adherence without deviation. Shall statements identify binding requirements. A go, no-go criterion.
- 6.13 Should - This word is used to identify an item which requires adherence if at all possible. Should statements identify preferred conditions.
- 6.14 State of Charge (SOC) - For vehicles operable in "RESS only mode," the SOC of the RESS is defined as the present capacity, (amperes-hours or watt-hours or miles), expressed as a percentage of the total available. The 100% SOC basis (available ampere-hours, kilowatt hours or miles) is determined by the actual discharge capability of the RESS when discharged to the requirements of the 45 mph Constant Speed Range Test portion of procedure ETA-HTP04.
- 6.15 Test Director - The individual within Electric Transportation Applications responsible for all testing activities associated with HEV America.
- 6.16 Test Director's Log - A daily diary kept by the Test Director, Program Manager, Test Manager or Test Engineer to document major activities and decisions that occur during the conduct of a Performance Test Evaluation Program. This log is normally a running commentary, utilizing timed and dated entries to document the day's activities. This log is edited to develop the Daily Test Log published with the final report for each vehicle.
- 6.17 Test Engineer - The individual(s) assigned responsibility for the conduct of any given test. [Each contractor/subcontractor should have at least one individual filling this position. If so, they shall be responsible for adhering to the requirements of this procedure.]

- 6.18 Test Manager - The individual within Electric Transportation Applications responsible for the implementation of the test program for any given vehicle(s) being evaluated to the requirements of HEV America. [Subcontract organizations may have similarly titled individuals, but they are not addressed by this procedure.]

7. REFERENCES

- 7.1 HEV America Vehicle Specification
- 7.2 ETA-HAC01 - "Control, Close-out and Storage of Documentation"
- 7.3 ETA-HAC02 - "Control of Test Conduct"
- 7.4 ETA-HAC04 - "Review of Test Results"
- 7.5 ETA-HAC06 - "Receipt Inspection"
- 7.6 ETA-HTP02 - "Implementation of SAE Standard J1666 May93, Electric Vehicle Acceleration, Gradeability and Deceleration Test Procedure"
- 7.7 ETA-HTP08 - "RESS Charging"
- 7.8 ETA-HTP11 - "Vehicle Verification"
- 7.9 SAE Standard J227a

APPENDIX-A
45 mph Constant Speed Range Test Data Sheet
(Page 1 of 2)

VIN Number: _____

Project No.:	Test Date(s):
Root File No.:	
Test Driver: <div style="text-align: center;">(Initials) (Date)</div>	
Test Engineer: <div style="text-align: center;">(Initials) (Date)</div>	

Vehicle Setup

VEHICLE WEIGHTS AS TESTED WITH DRIVER & INSTRUMENTATION (Test Weight is Curb Weight plus 332 pounds)			
Left Front: <div style="text-align: center;">(lbs or kg)</div>	Right Front: <div style="text-align: center;">(lbs or kg)</div>	Total Front: <div style="text-align: center;">(lbs or kg)</div>	Percent Front: %
Left Rear: <div style="text-align: center;">(lbs or kg)</div>	Right Rear: <div style="text-align: center;">(lbs or kg)</div>	Total Rear: <div style="text-align: center;">(lbs or kg)</div>	Percent Rear: %
		Total Weight: <div style="text-align: center;">(lbs or kg)</div>	
INSTALLED TIRES (Placard or sidewall whichever is less)			
Preparation Area Temperature: <div style="text-align: center;">(°F or °C)</div>			
Left Front		Right Front	
Pressure: <div style="text-align: center;">(psi or kPa)</div>		Pressure: <div style="text-align: center;">(psi or kPa)</div>	
Left Rear		Right Rear	
Pressure: <div style="text-align: center;">(psi or kPa)</div>		Pressure: <div style="text-align: center;">(psi or kPa)</div>	

Track/Weather Conditions

Test Track Location:	Track Grade: %
Ambient Temperature (initial): <div style="text-align: center;">(40-100°F or 5-38°C)</div>	Ambient Temperature (final): <div style="text-align: center;">(40-100°F or 5-38°C)</div>
Track Temperature (initial): <div style="text-align: center;">(°F or °C)</div>	Track Temperature (final): <div style="text-align: center;">(°F or °C)</div>
Wind Velocity (initial): <div style="text-align: center;">(<10 mph or 16 km/h)</div>	Wind Velocity (final): <div style="text-align: center;">(<10 mph or 16 km/h)</div>
Wind Direction (initial): °	Wind Direction (completion): °

VIN Number _____

APPENDIX-B
Maximum Achievable Speed Range Test Data Sheet
(Page 1 of 2)

VIN Number: _____

Project No.:	Test Date(s):
Root File No.:	
Test Driver:	
(Initials)	(Date)
Test Engineer:	
(Initials)	(Date)

Vehicle Setup

VEHICLE WEIGHTS AS TESTED WITH DRIVER & INSTRUMENTATION (Test Weight is Curb Weight plus 332 pounds)			
Left Front: <small>(lbs or kg)</small>	Right Front: <small>(lbs or kg)</small>	Total Front: <small>(lbs or kg)</small>	Percent Front: %
Left Rear: <small>(lbs or kg)</small>	Right Rear: <small>(lbs or kg)</small>	Total Rear: <small>(lbs or kg)</small>	Percent Rear: %
		Total Weight: <small>(lbs or kg)</small>	
INSTALLED TIRES (Placard or sidewall whichever is less)			
Preparation Area Temperature: <small>(°F or °C)</small>			
Left Front		Right Front	
Pressure: <small>(psi or kPa)</small>		Pressure: <small>(psi or kPa)</small>	
Left Rear		Right Rear	
Pressure: <small>(psi or kPa)</small>		Pressure: <small>(psi or kPa)</small>	

Track/Weather Conditions

Test Track Location:	Track Grade: %
Ambient Temperature (initial): <small>(40-100°F or 5-38°C)</small>	Ambient Temperature (final): <small>(40-100°F or 5-38°C)</small>
Track Temperature (initial): <small>(°F or °C)</small>	Track Temperature (final): <small>(°F or °C)</small>
Wind Velocity (initial): <small>(<10 mph or 16 km/h)</small>	Wind Velocity (final): <small>(<10 mph or 16 km/h)</small>
Wind Direction (initial): °	Wind Direction (completion): °

APPENDIX-B
Maximum Achievable Speed Range Test Data Sheet
(Page 2 of 2)

VIN Number _____

[illegible]

APPENDIX-C
Calibration of Vehicle Speedometer Test Data Sheet
(Page 1 of 1)

VIN Number: _____

Sequence No:	File No.:	Direction of Travel:
Time (initial):		Time (final):
Odometer (initial): <small>(miles or kilometers)</small>		Odometer (final): <small>(miles or kilometers)</small>
State of Charge (initial): <small>(SOC,KWH,AH)</small>		State of Charge (final): <small>(SOC,KWH,AH)</small>
DAS Heads-up Display:	Vehicle Speedometer:	
20 MPH		
25 MPH		
30 MPH		
35 MPH		
40 MPH		
45 MPH		
50 MPH		
55 MPH		
60 MPH		
70 MPH		
80 MPH		
MPH		
MPH		
Comments (initials/date): <hr/> <hr/> <hr/> <hr/> <hr/> <hr/> <hr/> <hr/> <hr/> <hr/>		
Completed By: _____ <small>(Printed Name) (Signature) (Date)</small>		
Reviewed By: _____ <small>(Printed Name) (Signature) (Date)</small>		
Approved By: _____ <small>(Printed Name) (Signature) (Date)</small>		

APPENDIX-D **Vehicle Metrology Setup Sheets** **(Page 1 of 1)**

VIN Number: _____

Instrument/Device:	Calibration Due Date:	Initials / Date:
Fifth Wheel S/N:		
Fifth Wheel Calibrator S/N:		
DAS S/N:		
DAS Set-up Sheet S/N		
kWh Meter S/N:		
Shunt S/N:		
Tire Pressure Gauge S/N:		
Misc:		
Misc:		
Misc:		
Misc:		
Comments (initials/date):		
<div style="height: 100px;"></div>		
Completed By:		
(Printed Name)	(Signature)	(Date)
Reviewed By (QA):		
(Printed Name)	(Signature)	(Date)
Approved By:		
(Printed Name)	(Signature)	(Date)